UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

AMAZIN' RAISINS INTERNATIONAL, INC. an Ontario, Canada corporation, Plaintiff,	)	
v.	)	Civ. Action No. 04-12679-MLW
OCEAN SPRAY CRANBERRIES, INC., a Delaware corporation, Defendant.	)	

DECLARATION OF KEITH CADWALLADER
IN SUPPORT OF PLAINTIFF'S OPPOSITION TO DEFENDANT'S
MOTION FOR SUMMARY JUDGMENT OF NONINFRINGEMENT

I, Keith Cadwallader, declare and state as follows:

1. I have a bachelor's degree in food science from the University of Georgia. I also have a masters degree from the University of Florida and a doctorate degree from the University of Florida, Gainesville, both in food science. Since earning my doctorate degree in 1990, I have been involved with research and development in the area of food chemistry. Currently, I work as an associate professor of food chemistry at the University of Illinois.

2. Attached hereto as Exhibit A is a true and accurate copy of my *curriculum vitae*.

3. I have read and reviewed United States Patent No. 5,188,861 ("the '861 patent"), entitled "Process For Preparing A Dried Fruit Product." I have also read the prosecution history of the '861 patent.

4. Those who work in the food chemistry and food processing industries would not understand the phrase "dried fruit" as requiring fruit to have a specific moisture content of 10 - 18%.

5. Based upon my review of the claims and specification of the '861 patent, as well as the prosecution history, it is my opinion that one of ordinary skill in the art of food processing would understand the term "dried fruit" as recited in claim 1 to mean a "fruit or fruit piece that has had a portion of its naturally occurring moisture content removed."

6. Attached hereto as Exhibit B is a true and accurate copy of an excerpt from the book entitled *Dehydration of Foods,* by Gustavo V. Barbosa-Canovas and Humberto Vega-Mercado (1996, Chapman and Hall, New York, pp. 1-3). As this text indicates, the phrase dried food refers to food that "has been exposed to a water removal process which has more than 2.5% water (dry basis)." (Ex. B, at 2-3.)

7. Based upon my review of the claims and specification of the '861 patent, as well as the prosecution history and my understanding of the principles of food chemistry, it is my opinion that one of ordinary skill in the art of food processing would understand the phrase "to substantially remove the natural flavor of the dried fruit" as meaning to modify the flavor components of the fruit so that the natural flavor of the dried fruit can no longer be perceived or recognized as such. To achieve this effect, the acidulant need not physically remove the natural flavor of the dried fruit. The fruit's natural flavor can effectively be removed by using an acidulant to alter the taste of the fruit such that its natural flavor can no longer be perceived to any significant degree. In other words, an acidulant can be used so as to effectively convince the consumer's senses that the natural flavor of the fruit is absent or removed. That is, the consumer would not be able to recognize the flavor as belonging to that fruit.

8. I have read and reviewed a copy of United States Pat. No. 5,320,861 ("the Mantius patent"), issued to Harold Mantius and assigned to Ocean Spray Cranberries, Inc. for a process entitled “Fruit Extraction and Infusion” which I understand discloses the Ocean Spray process

that Amazin' Raisins has accused of infringement. I have also inspected the Ocean Spray manufacturing plant located in Tomah, Wisconsin, where Ocean Spray uses the accused process. I have also reviewed the transcripts from the depositions of Michael Scott and Harold Mantius.

9. Based upon my review of these sources, I understand that Ocean Spray subjects frozen, sliced cranberries to a countercurrent extraction process to form what it calls "decharacterized fruit pieces." I also understand that these decharacterized fruit pieces are subsequently treated with an infusion syrup to recharacterize the fruit.

10. Ocean Spray removes the juice from the cranberries in order to manufacture cranberry juice. Thus, the decharacterized fruit pieces used by Ocean Spray have had a portion of their native moisture content removed. Specifically, Ocean Spray removes the liquid that is naturally present in cranberries during the countercurrent extraction process. Accordingly, Ocean Spray begins the infusion process with a "dried fruit" as that phrase is used in claim 1.

11. The decharacterized fruit pieces used by Ocean Spray in the accused process would be interchangeable with dried fruit such as raisins in the process of claim 1. Both can function as a carrier for flavoring agent to produce a fruit piece having a flavor that does not substantially correspond to the natural flavor of the original fruit.

12. I understand that Mr. Scott testified that Ocean Spray's decharacterized fruit pieces have a cranberry bite to them. This indicates that cranberry flavor remains in the decharacterized fruit pieces following countercurrent extraction or juice removal. I also understand that Mr. Scott specifically testified that the decharacterized fruit pieces still contain some cranberry juice after they have gone through the juice removal process.

13. Both Mr. Scott and Mr. Mantius testified that Ocean Spray treats the decharacterized fruit pieces with an infusion syrup that contains citric acid. Citric acid is an acidulant commonly

used in the industry.

14. Ocean Spray claims that it adds citric acid to the infusion syrup to mimic or intimate the taste of cranberries, since much of the cranberry flavor has been removed during the countercurrent extraction process. The taste of a cranberry comes from more than just citric acid. Citric acid is present in a large number of fruits, including oranges, lemons, limes, and other citrus fruits. It generally has a bitter taste, and someone who consumed citric acid would not associate its taste with cranberries. The fact that citric acid alone would not mimic a cranberry flavor is exemplified by the fact that Ocean Spray uses cranberry concentrate when manufacturing cranberry flavored fruit pieces as testified by Mr. Scott and Mr. Mantius. If citric acid was adequate to mimic a cranberry flavor, Ocean Spray's use of cranberry concentrate would not be necessary.

15. In addition, it would not make sense to add citric acid to mimic a cranberry flavor when trying to produce a product having a non-cranberry flavor. For instance, as discussed in the deposition of Mr. Mantius, Ocean Spray's orange infusion syrup contains citric acid and Orange WONF Durarome. The orange WONF Durarome is a flavoring agent providing the essential orange flavor character. As I mentioned, citric acid alone would not intimate a cranberry flavor, nor would it intimate any other fruit flavor for that matter. In addition, it would not make sense to add citric acid for the purpose of mimicking cranberry flavor when making an orange-flavored product.

16. Ocean Spray's use of citric acid in combination with the high Brix sugar in the infusion syrup serves to render the consumer unable to perceive any residual cranberry flavor, and it would overpower any residual cranberry flavorants. In other words, the use of citric acid in the infusion syrup results in an infused fruit piece that does not taste, to any significant degree,

like cranberry.

17. Whether someone uses an acidulant to remove flavor or to render that flavor imperceptible, the result would be the same. The processes are interchangeable and would be considered equivalent by those of us in the food chemistry industry.

I declare under the penalty of perjury that the foregoing is true and accurate. Executed on this 9th day of February 2006.

s/Keith Cadwallader
Keith Cadwallader

Keith R. Cadwallader

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Education

University of Florida, Gainesville, FL	Fall, 1990	Ph.D. Food Science (Chem. minor)
University of Florida	Summer. 1987	M.S. Food Science
University of Georgia, Athens, GA	Spring, 1985	B.S. Food Science

Professional Experience

1999-present. Associate Professor of Food Chemistry, Department of Food Science and Human Nutrition, University of Illinois. **Research Interests:** Chemistry and analysis of food flavor. Food flavor (aroma) characterization and food flavor quality determination. Use of instrumental and sensory methods to identify and quantify character-impact flavor compounds in foods/agricultural/industrial materials. Development of process flavors. Recovery of flavor constituents from food processing by-products. Measurement and prediction of flavor diffusion, release and binding.

1996-1999. Associate Professor of Food Science, Food Science & Technology, Mississippi State Univ.

1994-1996. Assistant Professor of Food Science, MSU

1991-1994. Assistant Professor of Food Science, Food Science, Louisiana State University.

1985-1990. Pre-doctoral Research Fellow, Food Science and Human Nutrition, University of Florida.

Current Appointment

Research – 60%; Teaching – 40%

Awards/Honors

- 1984 U. Georgia Food Science Department Faculty Scholarship Recipient
- 1985-1990 FMC Corp. Research Fellowship Recipient
- 1996 Alpha Zeta Outstanding Teaching Award
- UIUC Incomplete list of teachers rated as excellent (Spr00, Fall00, Fall01, Spr03, Spr04, Spr05)
- Phi Tau Sigma Food Science Honorary Society, 1994-present

Professional Memberships

Institute of Food Technologists
IFT, Chicago Section
American Chemical Society
Division of Agricultural and Food Chemistry
(division and programming chair, 2003-2004)

Research Activities (narrative)

Over the past 14 years as a university professor, I have edited three books, and published 28 book chapters and 55 journal articles in the area of food flavor chemistry and analysis. Among these, during my tenure at UIUC I have published over 16 book chapters and 29 journal articles.

Much of my research has been published in the highest impact journals in the field of food chemistry, such as *Journal of Agricultural and Food Chemistry* (19) of the American Chemical Society and *Journal of Food Science* (19), as well as other highly respected journals (e.g. *J. Sensory Studies, J. American Oil Chemists Society, Cereal Chemistry, Lebemsm.-Wiss. u. Technol., J. Dairy Science*). In addition, I have presented >30 invited symposium papers and >75 scientific papers at national scientific meetings.

During my tenure at UIUC, I have served as principal investigator (10) or co-PI (8) on eighteen extramurally funded projects totaling over $2.5M in research dollars. I am also co-PI with researchers from the Chemical and Biomolecular Engineering Department (Masel et al.) on a $4.5M project.

Campus-based Research Contributions and Support

In addition to advising and mentoring undergraduate students, graduate students (4 completed at UIUC), post doctoral researchers and visiting scientists, I also serve as the director of two campus Centers and one Managed Research Area that help promote and support research by UIUC scientists.

- Director of the *College of ACES Center for Mass Spectrometry (CMS)* since 1999. The CMS serves as an advanced analytical resource for both my own research activities and those of other faculty, staff and students within the college and university. The CMS is a well-equipped facility that maintains analytical capabilities in tandem mass spectrometry applications (GC-MS, LC-MS, and high resolution MS), as well as other routine analytical instrumentation (GC, LC, dynamic vapor sorption, etc.). The CMS specialize in training of staff and graduate students on the proper use of the instrumentation and encourages them to perform their own analyses (at reduced cost). On occasion, the CMS will perform analyses for UIUC researchers and outside companies. Annually, the CMS generates >$25,000 in revenues related to analytical service and training activities.
- Director (Co-director from 2000-2002) of the Illinois Center for Soy Foods (ICSF, established with funds of $1,041,600 provided by the CFAR-Sentinel program). The ICSF is comprised of a multidisciplinary team of faculty, staff and students devoted to the promotion of the consumption of soy foods through applied research and outreach activities thereby seeking to provide financial benefits to growers and processors in the state, technological innovations to large and small-scale processors globally, as well as health benefits to consumers. The center conducts much of its own research projects, but also has awarded research (seed) grants (>$100,000) to UIUC faculty to target a number of issues related to soy consumption. During 2004, the Center received external financial support of more than $750,000 from the federal government and the soybean industry.
- Director of the Soy Foods Managed Research Area (MRA) established in 2003 with funds provided by the Illinois Soybean Checkoff Board. The mission of the Soy Foods MRA is to connect the Illinois Soybean Program Operating Board with leading food scientists, nutritionists and other researchers in an effort to promote the further development and consumption of soy foods through targeted research areas. Currently the MRA supports four research projects directed by UIUC faculty.

Publications

Books (3)

Cadwallader, K.R. and Weenen, H. (Eds.). 2003. *Freshness and Shelf Life of Foods.* ACS Symposium Series 836, American Chemical Society, Washington, DC.

Rouseff, R.L. and Cadwallader, K.R. (Eds.). 2001. *Headspace Analysis of Foods and Flavor: Theory and Practice.* Kluwer Academic/Plennum Publishers, New York.

Shahidi, F. and Cadwallader, K.R. (Eds.). 1997. *Flavor and Lipid Chemistry of Seafoods.* ACS Symposium Series 674. American Chemical Society, Washington, DC.

Book Chapters (refereed)

Cadwallader, K.R. 200X. Wood smoke flavor. In *Flavor Technology*. Hui, Y.H., Nollet, L.M.L., Boylsten, T., Beatriz, M., Chen, F. and Peris-Tortajada, M (Eds.), DEStech Publications, Inc., Lancaster, PA (forthcoming)

Singh, T.K., Drake, M.A. and Cadwallader, K.R. 200X. Flavor of dairy products. In *Flavor Technology*. Hui, Y.H., Nollet, L.M.L., Boylsten, T., Beatriz, M., Chen, F. and Peris-Tortajada, M (Eds.), DEStech Publications, Inc., Lancaster, PA (forthcoming)

Jarunrattanasri, A., Cadwallader, K.R., Theerakulkait, C. 2005. Aroma and amino acid composition of hydrolyzed vegetable protein from rice bran. In *Process and Reaction Flavors*, Weerasinghe, D.K. (Ed.), ACS Symposium Series 905, American Chemical Society, Washington, DC, pp. 83-97.

Cadwallader, K.R., Benitez, D., Pojjanapimol, S., Syriyaphan, O. and Singh, T. 2005. Characteristic aroma components of the cilantro mimics. In. *Natural Flavors and Fragrances*, Frey, C. and Rouseff, R. (Eds.), ACS Symposium Series 908, American Chemical Society, Washington, DC, pp. 117-128.

Cadwallader, K.R. 2005. Flavor and volatile metabolism in produce. Chapter 6. In *Produce Degradation: Pathways and Prevention*, Lamikanra, O., Imam, S.H. and Ukuku, D.O. (Eds.), CRC Press LLC, Boca Raton, FL, pp 155-189.

Pojjanapimol, S., Chaiseri, S. and Cadwallader, K. 2004. Heat-induced changes in aroma components of holy basil (*Ocimum sanctum* L.). Ch. 15. In *Handbook of Flavor Characterization: Sensory analysis, chemistry, and physiology*, Diebler, K.D. and Delwiche, J. (Eds.), Marcel Dekker, Inc., New York, pp. 217-230.

Singh, T.K. and Cadwallader, K.R. 2004. Ways of Measuring Shelf-life and Spoilage. Ch. 9. In *Understanding and Measuring the Shelf-life of Food*, Steele, R. (Ed.). CRC Press LLC, Boca Raton, FL, pp. 165-183.

Cadwallader, K.R., Lopez, J.R., Menke, S.D. and Surakarnkul, R. 2003. Aroma components of

wines from Chardonel - A French-American hybrid grape. In *Nutraceutical Beverages. Chemistry, Nutrition, and Health Effects*, Shahidi, F. and Weerasinghe, D.K. (Eds.), ACS Symposium Series 871. American Chemical Society, Washington, DC, Chapter 27.

Karagül-Yüceer, Y., Drake, M.A. and Cadwallader, K.R. 2002. Aroma characterization of fresh and stored nonfat dry milk. In *Freshness and Shelf Life of Foods.* Cadwallader, K.R. and Weenen, H. (Eds.), ACS Symposium Series 836, American Chemical Society, Washington, DC, pp. 108-123.

Singh, T.K. and Cadwallader, K.R. 2002. The Shelf Life of Foods: An Overview. In *Freshness and Shelf Life of Foods.* Cadwallader, K.R. and Weenen, H. (Eds.), ACS Symposium Series 836. American Chemical Society, Washington, DC, pp. 2-21.

Cadwallader, K.R. 2001. Flavor chemistry of saffron. In *Carotenoid-derived Aroma Compounds.* Winterhalter, P. and Rouseff, R.L. (Eds.). ACS Symposium Series 802, American Chemical Society, Washington, DC, pp. 220-239.

Cadwallader, K.R. and Heo, J. 2001. Aroma of Roasted Sesame Oil: Characterization by Direct Thermal Desorption-Gas Chromatography-Olfactometry and Sample Dilution Analysis. In *Gas Chromatography-Olfactometry: The State of the Art.* Leland, J.V.; Schieberle, P.; Buettner, A.; Acree, T.E. (Eds.). ACS Symposium Series 782; American Chemical Society, Washington, DC, pp. 187-202.

Cadwallader, K.R. and Shahidi, F. 2001. Identification of Potent Odorants in Seal Blubber Oil by Direct Thermal Desorption-Gas Chromatography-Olfactometry. In *Omega-3 Fatty Acids: Chemistry, Nutrition, and Health Effects.* Shahidi, F. and Finley, J.W. (Eds.) ACS Symposium Series 788; American Chemical Society, Washington, DC, pp. 221-234.

Webb, T.E. and Cadwallader, K.R. 2001. Aroma components of an oil-based grill flavoring by direct thermal desorption-gas chromatography-olfactometry and sample dilution analysis. In *Headspace Analysis of Foods and Flavor: Theory and Practice.* Rouseff, R.L. and Cadwallader, K.R., (Eds.). Kluwer Academic/Plennum Publishers, New York, pp. 143-150.

Cadwallader, K.R. 2000. Flavor recovery from crustacean processing by-products. In *Seafood in Health and Nutrition. Transformation in Fisheries and Aquaculture: Global Perspectives.* Shahidi, F. (Ed.). ScienceTech Publishing Co., St. John's, Canada, Ch. 12, pp. 159-168.

Cadwallader, K.R. 2000. Enzymes and flavor biogenesis in fish. In *Seafood Enzymes.* Haard, N.F. and Simpson, B.K. (Eds.). Marcel Dekker, Inc., New York, pp. 365-383.

Cadwallader, K.R., Surakarnkul, R., Yang, S.-P., and Webb, T. 1999. Character-impact aroma components of coriander (*Coriandrum sativum*) herb. In *Flavor and Chemistry of Ethnic Foods.* Shahidi, F. and Ho, C.-T. (Eds.). Plenum Publishing Corporation, New York.

Cadwallader, K.R. and Baek, H.H. 1998. Aroma-impact components in cooked tailmeat of

freshwater crayfish (*Procambarus clarkii*). In *Proceedings of the Ninth International Flavor Conference, George Charalambous Memorial Symposium.* Mussinan, C., Contis, E., Ho, C.-T., Parliment, T., Spanier, A., Shahidi, F. (Eds.). Elsevier Science B.V., Amsterdam.

Cadwallader, K.R. and Howard, C.L. 1998. Analysis of aroma-components of light-activated milk. In *Flavor Analysis: Developments in Isolation and Characterization.* Mussinan, C.J. and Morello, M.J. (Eds.). ACS Symposium Series 705. American Chemical Society, Washington, DC, pp. 343-358.

Cadwallader, K.R. and MacLeod, A.J. 1998. Instrumental methods for analyzing the flavor of muscle foods. Ch. 16. In *Flavor of Meat, Meat Products, and Seafoods, 2nd Ed.* Shahidi, F. (Ed.). Blackie Academic & Professional, New York.

Baek, H.H. and Cadwallader, K.R. 1997. Character-impact aroma components of crustaceans. In *Flavor and Lipid Chemistry of Seafoods*, Shahidi, F. and Cadwallader, K.R. (Eds.). ACS Symposium Series. 674. American Chemical Society, Washington, DC, pp. 85-94.

Weng, H.-J., Cadwallader, K.R., Baek, H.H., D'Abramo, L.R.D., and Sullivan, J.A. 1997. Manipulating the flavor of freshwater crustacea using postharvest seawater acclimation. In *Flavor and Lipid Chemistry of Seafoods*, Shahidi, F. and Cadwallader, K.R. (Eds.). ACS Symposium Series. 674. American Chemical Society, Washington, DC, pp. 120-130.

Cha, Y.J., Lee, G.H., Cadwallader, K.R. 1997. Aroma-active compounds in salt-fermented anchovy. In *Flavor and Lipid Chemistry of Seafoods,* Shahidi, F. and Cadwallader, K.R. (Eds.). ACS Symposium Series. 674. American Chemical Society, Washington, DC, pp. 131-147.

Shahidi, F. and Cadwallader, K.R. 1997. Flavor and lipid chemistry of seafoods: An overview. In *Flavor and Lipid Chemistry of Seafoods*, Shahidi, F. and Cadwallader, K.R. (Eds.). ACS Symposium Series 674. American Chemical Society, Washington, DC, pp. 1-8.

Cadwallader, K.R., Baek, H.H., and Cai, M. 1997. Characterization of saffron flavor by aroma extract dilution analysis. In *Spices: Flavor Chemistry and Antioxidant Properties.,* Risch, S.J. and Ho, C.-T. (Eds.). ACS Symposium Series 660. American Chemical Society, Washington, DC, pp. 66-79.

Braddock, R.J. and Cadwallader, K.R. 1995. Bioconversion of citrus d-limonene. In *Fruit Flavors: Biogenesis, Characterization, and Authentication,* Rouseff, R.L. and Leahy, M.M. (Eds.). ACS Symposium Series 596. American Chemical Society, Washington, DC, pp. 142-147.

Cadwallader, K.R., Baek, H.H., Chung, H.Y., and Moody, M.W. 1994. Contribution of lipid-derived components to the flavor of alligator meat. In *Lipids in Food Flavors,* Ho, C.T. and Hartman, T.G. (Eds.) ACS Symposium Series No. 558. American Chemical Society, Washington, DC, pp. 186-195.

Cadwallader, K.R. and Braddock, R.J. 1992. Enzymatic hydration of (4R)-(+)-limonene to (4R)-

(+)-α-terpineol. In *Developments in Food Science: Food Science and Human Nutrition*, Volume 29, Charalambous, G. (Ed.) Elsevier, New York, pp. 571-584.

Journal Articles

Bohn DM, Cadwallader KR, and Schmidt SJ. 2005. Development and validation of a dynamic vapor sorption-fast gas chromatography-flame ionization detection method for rapid analysis of volatile release from glassy matrices. J. Agric. Food Chem. 53: 3149-3155.

Bohn DM, Cadwallader KR, and Schmidt SJ. 2005. Use of DSC, DVS-DSC, and DVS-fast GC-FID to evaluate the physicochemical cChanges that occur in artificial cherry Durarome® upon humidification. J Food Sci 70(2): E109-16.

Carunchia-Whetstine, M.E., Cadwallader, K.R. and Drake, MA. 2005. Characterization of aroma compounds responsible for rosey/floral flavor in Cheddar cheese. J. Agric. Food Chem. 53: 3126-3132.

Singh, T.K., Young, N.D., Drake, K.R. and Cadwallader, K.R. 2005. Production and sensory characterization of a bitter peptide from beta-casein. J. Agric. Food Chem. 53: 1185-1189.

Alasalvar, C., Odabasi, A.Z., Demir, N., Balaban, M.O., Shahidi, F. and Cadwallader, K.R. 2004. Volatiles and flavor of five Turkish hazelnut varieties as evaluated by descriptive sensory analysis, electronic nose, and dynamic headspace analysis/gas chromatography-mass spectrometry. J. Food Sci. 69:99-106.

Avsar, Y.K., Karagul-Yuceer, Y., Drake, M.A., Singh, T.K., Yoon, Y. and Cadwallader, K.R. 2004. Characterization of nutty flavor in Cheddar cheese. J. Dairy Sci. 87:1999-2010.

Brisske, L.K., Lee, S.-Y., Klein, B.P., Cadwallader, K.R. 2004. Development of a prototype high-energy, nutrient dense food product for emergency relief. J. Food Sci. 69(9): S361-S367.

Zhou, Q. and Cadwallader, K.R. 2004. Inverse gas chromatographic method for measurement of interactions between soy protein isolate and selected flavor compounds under controlled relative humidity. *J. Agric. Food Chem.* 52: 6271-6277.

Zhou, Q., Guthrie, B. and Cadwallader, K.R. 2004. Development of a system for measurement of permeability of aroma compounds through multilayer polymer films by coupling dynamic vapor sorption with purge-and-trap/fast gas chromatography. Packaging Technol. Sci. 17:175-185.

Singh, T.K., Drake, M.A. and Cadwallader, K.R. 2003. Flavor of Cheddar cheese: A chemical and sensory perspective. Comprehensive Reviews in Food Science and Food Safety (CRFSFS) 2: 139-162.

Karagul-Yuceer, Y., Vlahovich, K.N., Drake, MA and Cadwallader, K.R. 2003. Characteristic

aroma components of rennet casein. *J. Agric. Food Chem.* 51: 6797-6801.

Kiatsrichart, S., Brewer, M.S., Cadwallader, K.R. and Artz, W.E. 2003. Pan frying stability of NuSun oil, a mid-oleic sunflower oil. J. Am. Oil. Chem. Soc. 80(5): 479-483.

Alasalvar, C., Shahidi, F. and Cadwallader, K.R. 2003. Comparision of natural and roasted Turkish Tombul hazelnut (*Corylus avellana* L.) volatiles and flavor by DHA/GC/MS and descriptive sensory analysis. J. Agric. Food Chem. 51(17): 5067-5072.

Drake, M.A., Karagul-Yuceer, Y., Cadwallader, K.R., Civille, G.V., and Tong, P.S. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. J. Sensory Studies 18(3): 199-216.

Karagul-Yuceer, Y., Drake, M.A. and Cadwallader, K.R. 2003. Aroma-active components of liquid Cheddar whey. J. Food Science 68(4): 1215-1219.

Drake, M.A., Gerard, P.D., Wright, S., Cadwallader, K.R., and Civille, G.V. 2002. Cross validation of a sensory language for Cheddar cheese. J. Sensory Studies 17: 215-227.

Karagul-Yuceer, Y., Cadwallader, K.R. and Drake, M.A. 2002. Volatile flavor components of stored nonfat dry milk. J. Agric. Food Chem. 50(2): 305-312.

Wu, Y.-F.G. and Cadwallader, K.R. 2002. Characterization of the aroma of a meat-like process flavoring from soybean-based enzyme-hydrolyzed vegetable protein. J. Agric. Food Chem. 50(10): 2900-2907.

Zhou, Q., Wintersteen, C.L. and Cadwallader, K.R. 2002. Identification and quantification of aroma-active components that contribute to the distinct malty flavor of buckwheat honey. J. Agric. Food Chem. 50(7): 2016-2021.

Baek, H.H., Kim, C.J., Ahn, B.A., Nam, H.S., Cadwallader, K.R. 2001. Aroma extract dilution analysis of a beeflike process flavor from extruded enzyme-hydrolyzed soybean protein. J. Agric. Food Chem. 49(2): 790-793.

Drake, M.A., McInvale, S.C., Gerard, P.D., Cadwallader, K.R. and Civille, G.V. 2001. Development of a descriptive language for Cheddar cheese. J. Food Sci. 66(9): 1422-1427.

Lee, G.H., Suriyaphan, O., Cadwallader, K.R. 2001. Aroma components of cooked tail meat of American lobster (*Homarus americanus*). J. Agric. Food Chem. 49(9): 4324-4332.

Karagul-Yuceer, Y., Drake, M.A. and Cadwallader, K.R. 2001. Aroma-active components of nonfat dried milk. J. Agric. Food Chem. 49(6): 2948-2953.

Suriyaphan, O., Drake, M.A., Chen, X.Q., Cadwallader, K.R. 2001. Characteristic aroma components of British Farmhouse Cheddar cheese. J. Agric. Food Chem. 49(3): 1382-1387.
Suriyaphan, O., Cadwallader, K.R., Drake, M.A. 2001. Lecithin associated flavors in fermented

dairy products. J. Food Sci. 66(4): 517-523.

Suriyaphan, O., Drake, M.A., Cadwallader, K.R. 2001. Lipid oxidation of deoiled soy lecithin by lactic acid bacteria. Lebensm.-Wiss. u.-Technol. 34: 462-468.
Yoo, S.K., Day, D.F., and Cadwallader, K.R. 2001. Bioconversion of α- and β-pinene by *Pseudomonas* sp. strain PIN. Process Biochem. 36: 925-932.

Wu, Y.-F., Baek, H.H. and Cadwallader, K.R. 2000. Development of a meatlike process flavoring from soybean-based enzyme-hydrolyzed vegetable protein. J. Food Sci. 65:1220-1227.

Kim, D.S., Baek, H.H., Ahn, C.B., Byun, D.S., Jung, K.J., Lee, H.G., Cadwallader, K.R., Kim, H.R. 2000. Development and characterization of a flavoring agent from oyster cooker effluent. J. Agric. Food Chem. 48: 4839-4843.

Bergman, C.J., Delgado, J.T., Bryant, R., Grimm, C., Cadwallader, K.R. and Webb, B.D. 2000. A rapid gas chromatographic technique for quantifying 2-acetyl-1-pyrroline and hexanal in rice (*Oryza sativa*, L.). Cereal Chem. 77(4): 454-458.

Baek, H.H. and Cadwallader, K.R. 1999. Contribution of free and glycosidically bound volatile compounds to the aroma of muscadine juice. J. Food Sci. 64: 441-444.

Baek, H.H. and Cadwallader, K.R. 1999. Optimization of the enzymatic hydrolysis of crab processing by-products using Flavourzyme™. Food Sci. Biotechnol. 8: 43-46.

Drake, M.A. Karagül-Yüceer, Chen, X.Q., and Cadwallader, K.R. 1999. Characterization of desirable and undesirable lactobacilli from cheese in fermented milk. Lebensm-Wiss. u.-Technol. 32: 433-439

Suriyaphan, O., Drake, M.A., Cadwallader, K.R. 1999. Identification of volatile off-flavors in reduced-fat Cheddar cheese containing lecithin. Lebensm-Wiss. u.-Technol. 32: 250-254.

Baek, H.H. and Cadwallader, K.R. 1998. Roasted chicory aroma evaluation by gas chromatography/mass spectrometry/olfactometry. J. Food Sci. 63: 234-237.

Cha, Y.J., Kim, H., and Cadwallader, K.R. 1998. Aroma-active compounds in Kimchi during fermentation. J. Agric. Food Chem. 46: 1944-1953.

Cha, Y.J. and Cadwallader, K.R. 1998. Aroma-active compounds in skipjack tuna sauce. J. Agric. Food Chem. 46: 1123-1128.

Tan, Q., Day, D.F., and Cadwallader, K.R. 1998. Bioconversion of (R)-(+)-limonene by *P. digitatum* (NRRL 1202). Process Biochem. 33: 29-37.

Baek, H.H., Cadwallader, K.R., Marroquin, E., and Silva, J.L. 1997. Identification of predominant aroma compounds in muscadine grape juice. J. Food Sci. 62: 249-252.
Baek, H.H. and Cadwallader, K.R. 1997. Aroma volatiles in cooked alligator meat. J. Food Sci.

62: 321-325.

Baek, H.H. and Cadwallader, K.R. 1996. Volatile compounds in flavor concentrates produced from crayfish-processing byproducts with and without protease treatment. J. Agric. Food Chem. 44: 3262-3267.

Andrews, L.S., Cadwallader, K.R., Grodner, R.M., and Chung, H.Y. 1995. Microbial and sensory quality of ground ginger as affected by gamma irradiation. J. Food Sci. 60: 829-832.

Baek, H.H. and Cadwallader, K.R. 1995. Enzymatic hydrolysis of crayfish processing by-products. J. Food Sci. 60: 929-935.

Cadwallader, K.R., Tan, Q., Chen, F., and Meyers, S.P. 1995. Evaluation of the aroma of cooked spiny lobster tail meat by aroma extract dilution analysis. J. Agric. Food Chem. 43: 2432-2437.

Cha, Y.J. and Cadwallader, K.R. 1995. Volatile components in salt-fermented fish and shrimp pastes. J. Food Sci. 60: 19-24.

Chung, H.Y., Chen, F., and Cadwallader, K.R. 1995. Cooked blue crab claw meat aroma compared with lump meat. J. Food Sci. 60: 289-291, 299.

Cadwallader, K.R. and Xu, Y. 1994. Analysis of volatile components in fresh grapefruit juice by purge and trap/gas chromatography. J. Agric. Food Chem. 42: 782-784.

Chung, H.Y. and Cadwallader, K.R. 1994. Aroma extract dilution analysis of blue crab claw meat volatiles. J. Agric. Food Chem. 42: 2867-2870.

Kim, H.R., Baek, H.H., Cadwallader, K.R., Meyers, S.P., and Godber, J.S. 1994. Improved flavor extractibility from crab waste using the hepatopancreatic enzyme of crawfish, *Procambarus clarkii*. J. Food Sci. 59: 91-96.

Cha, Y.J., Cadwallader, K.R., and Baek, H.H. 1993. Volatile flavor components in snow crab cooker effluent and effluent concentrate. J. Food Sci. 58: 525-530.

Chung, H.Y. and Cadwallader, K.R. 1993. Volatile components in blue crab (*Callinectes sapidus*) meat and processing by-product. J. Food Sci. 58: 1203-1207, 1211.

Braddock, R.J. and Cadwallader, K.R. 1992. Citrus by-products manufacture for food use. Food Technol. 46(2): 105-110.

Cadwallader, K.R., Braddock, R.J. and Parish, M.E. 1992. Isolation of α-terpineol dehydratase from *Pseudomonas gladioli*. J. Food Sci. 57: 241-244, 248.
Cadwallader, K.R., Braddock, R.J., Parish, M.E. and Higgins, D.P. 1989. Bioconversion of (+)-limonene by *Pseudomonas gladioli.* J. Food Sci. 54: 1241-1245.

Braddock, R.J., Temelli, F. and Cadwallader, K.R. 1986. Citrus essential oils – a dossier for

materials safety data sheets. Food Technol. 40(11): 114-116.

Other publications

Cadwallader, K.R., Klein, B.P., Sullivan, C.L., Nash, M., Khanna, P. and Weingartner, K.E. 2003. *Soy for the Last Minute Chef.* Illinois Center for Soy Foods, University of Illinois, University Board of Trustees, Urbana, IL.

Klein, B.P., Cadwallader, K.R., Chen, D., Khanna, P., Sullivan, C.L. and Weingartner, K.E. 2003. *Baking with Soy*. Illinois Center for Soy Foods, University of Illinois, University Board of Trustees, Urbana, IL.

Klein, B.P., Cadwallader, K.R., Chen, D., Khanna, P., Sullivan, C.L. and Weingartner, K.E. 2002. *Textured Vegetable Protein in the American Kitchen.* Illinois Center for Soy Foods, University of Illinois, University Board of Trustees, Urbana, IL.

Klein, B.P., Cadwallader, K.R., Chen, D., Khanna, P. and Weingartner, K.E. 2002. *Tofu in the American Kitchen.* Illinois Center for Soy Foods, University of Illinois, University Board of Trustees, Urbana, IL.

Invited (Symposium) Papers (2003-2005)

Rotsachakul, P., Cadwallader, K.R. and Chaiseri, S. 2005. Comparison of DHS and solvent extraction-SAFE for GCO-dilution analysis of key aroma components of Thai fried chili paste. ACS Symposium: *Aroma-active Compounds in Foods and Reaction Flavors: Formation, Measurement and Stability*. (Ho, C.-T., Weerasinghe, D.K. and Cadwallader, K.R., organizers). 330th ACS National Meeting, Washington, DC, August 28 – September 1, AGFD paper 9.

Cadwallader, K.R., Bordignon, J.R., Wang, P. and Sugiharto, R. 2005. Identification of odorants responsible for off-flavor of corn gluten meal. ACS Symposium: *Grain-based Products: Health and Flavor, and Safety Aspects* (Cadwallader, K.R., Schieberle, P. and Morello, M.J., organizers). 330th ACS National Meeting, Washington, DC, August 28 – September 1, AGFD paper 167.

Gnadt, T.A., Jasso, L. and Cadwallader, K.R. 2005. Characteristic aroma components of chipotle peppers. ACS Symposium: *Chemistry and Flavor of Hispanic Foods* (de Mejia, E. and Tunick, M.H., organizers). 229th ACS National Meeting, San Diego, CA, March 13-17.

Lozano, P.R., Nicolalde, C.L. and Cadwallader, K.R. 2005. Identification of characteristic aroma components of mate (*Ilex paraguariensis*) tea. ACS Symposium: *Chemistry and Flavor of Hispanic Foods* (de Mejia, E. and Tunick, M.H., organizers). 229th ACS National Meeting, San Diego, CA, March 13-17.

Lecona-Uribe, S., Loarca-Piña, G., Arcila-Lozano, C.C. and Cadwallader, K.R. 2005. Chemical

composition of essential oil from Mexican orégano. ACS Symposium: *Chemistry and Flavor of Hispanic Foods* (de Mejia, E. and Tunick, M.H., organizers). 229th ACS National Meeting, San Diego, CA, March 13-17.

Cadwallader, K.R. 2004. Recent developments in headspace GC for routine monitoring of volatile lipid oxidation products. AGFD (AOCS) Symposium: Measuring and Reducing Lipid Oxidation in Food Systems. Artz, W.E. (organizer). ACS 36th Great Lakes Regional Meeting, Peoria, IL, October 17-20.

Drake, K.R. and Cadwallader, K.R. 2004. Establishing links between sensory and instrumental analysis of dairy flavors. ACS Symposium: *Chemistry and Flavor of Dairy Products.* (Cadwallader, K.R., Drake, M.A., and McGorrin, R.J., organizers). 228th ACS National Meeting, Philadelphia, PA, August 22-26.

Singh, T.K. and Cadwallader, K.R. 2004. Streamlined analysis of free fatty acids in dairy products. ACS Symposium: *Chemistry and Flavor of Dairy Products.* (Cadwallader, K.R., Drake, M.A., and McGorrin, R.J., organizers). 228th ACS National Meeting, Philadelphia, PA, August 22-26.

Cadwallader, K.R. 2004. Importance of sample preparation technique on the composition of aroma extracts from fresh herbs. ACS Symposium: *Challenges in Herb Research – Chemical Analysis and Quality* (Ho, C.T. and Hwang, L.S., organizers). 227th ACS National Meeting, Anaheim, CA, March 28-April 1.

Cadwallader, K.R., Jarunrattanasri, A. and Theerakulkait, C. 2003. Aroma components of HVP made from rice bran protein. ACS Symposium: *Processed/Reaction Flavors, Ingredients and Intermediate Reactions* (Weerasinghe, D.K. and Sucan, M.K., organizers). 226h ACS National Meeting, New York, NY, September 7-11.

Cadwallader, K.R. and Pojjanapimol, S. 2003. Characteristic aroma components of the cilantro mimics. ACS Symposium: *Natural Flavor and Fragrance Ingredients: Chemistry, Production and Application.* (Frey, C. and Rouseff, R.L., organizers). 226h ACS National Meeting, New York, NY, September 7-11.

Cadwallader, K.R. Relating Cheddar cheese flavor to chemical components. 2003. IFT Symposium: Flavor Chemistry of Dairy Products. (Drake, M.A. and Cadwallader, K.R., organizers). Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #52-5.

Volunteered Abstracts (2003-2005)

Gnadt, T.A., Jasso, L. and Cadwallader, K.R. 2005. Comparison of direct solvent extraction and dynamic headspace sampling for the analysis of characteristic aroma components of chipotle pepper. Annual Meeting of the Institute of Food Technologists, New Orleans, LA, July 16-20, #17D-34.

Klein, B.P., Khanna, P., Cadwallader, K.R. and Endres, J.M. 2005. Reducing fat in school

lunches by using soy-enhanced entrees. Annual Meeting of the Institute of Food Technologists, New Orleans, LA, July 16-20, #70E-27.

Nowak, M.C., Singh, T.K. and Cadwallader, K.R. 2005. Identification of potent odorants in commercial hickory and mesquite liquid smoke. Annual Meeting of the Institute of Food Technologists, New Orleans, LA, July 16-20, #17D-36.

Song, H. and Cadwallader, K.R. 2005. Aroma components of American country-style ham. Annual Meeting of the Institute of Food Technologists, New Orleans, LA, July 16-20, #17D-35

Yu, X., Song, Y.S. and Cadwallader, K.R. 2005. Identification of the characteristic aroma components of commercial dried California bay leaves (*Laurus nobilis* L.). Annual Meeting of the Institute of Food Technologists, New Orleans, LA, July 16-20, #17D-19.

Zhou, Q. and Cadwallader, K.R. 2005. Application of IGC for measurement of binding of volatile flavor compounds by soy proteins in low-moisture food systems. 229th ACS National Meeting, San Diego, CA, March 13-17.

Bohn, D.M. Cadwallader, K.R. and Schmidt, S.J. 2004. Kinetic analysis of benzaldehyde release in artificial cherry Durarome® upon humidification using dynamic vapor sorption-fast gas chromatography-flame ionization detection. Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, #114B-27.

Lopez, J.R., Cadwallader K.R. and Menke, S.D. 2004. Menke Aroma-impact components of Illinois Frontenac wine. Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, #83D-3.

Singh, T.K., Young, N.D., Drake, M.A., Cadwallader, K.R. 2004. Production of a bitter peptide from casein and its sensory characterization. Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, #17B-17.

Ugarte-Romero, E.E. Feng, H, Martin, S.E. and Cadwallader, K.R. 2004. Power ultrasound as an alternative for apple cider pasteurization. Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, #32-10.

Yoon, Y., Carunchia-Whetstine, M.E., Friedeck, K.G., Drake, M.A. and Cadwallader, K.R. 2004. Characterization of aroma-active compounds in fresh sweet cherry cultivars. Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, #114B-3.

Zhou, Q. and Cadwallader, K.R. 2004. Investigation of flavor-soy protein interactions under controlled relative humidity by inverse gas chromatography (IGC). Annual Meeting of the Institute of Food Technologists, Las Vegas, NV, July 12-16, # 114B-2.

Brisske, L.K., Lee, S.Y., Klein, B.P. and Cadwallader, K.R. 2003 Consumer ratings of energy bars:

Should the bar be raised? Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #12-2.

Bohn, D.M., Cadwallader, K.R. and Schmidt, S.J. 2003. Measurement of volatile release from an amorphous carbohydrate matrix as a function of relative humidity using dynamic vapor sorption technology. Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #12-2.

Singh, T.K., Drake, M.A. and Cadwallader, K.R. 2003. Characterization of aroma components of Muenster cheese by aroma extract dilution and headspace dilution analyses. Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #71-3.

Suriyaphan, O., Zhou, Q. and Cadwallader, K.R. 2003. Identification of key aroma components of Piper betel L. leaf. Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #45C-16.

Short Courses/Symposia (2003-2005)

Organizer

Obesity Management: Role of Soy Foods. University of Illinois, Champaign, IL, May 25-26, 2005.

A Place for Soy in a Better School Lunch Program. University of Illinois, Urbana, IL, March 12, 2003.

Participant (as instructor)

Cadwallader, K.R. Flavoring soy products: masking and creating. Preconference AOAC Short Course. Soyfoods: Ingredients, Preparation, and Utilization, Koseoglu, S. and Shahidi, F. (organizers), Cincinnati, OH, May 9, 2005.

Cadwallader, K.R. 2004. Aroma and flavor aspects of soy beverages. Preconference Shortcourse: *Functional Beverages*, Koseoglu, S and Shahidi, F. (organizers), Worldnutra: International Conference and Exhibition on Nutraceutacals and Functional Foods, San Francisco, CA, Nov 8, 2004

Flavor Research Workshop. ACS Short Course (Acree, T.E., course director), American Chemical Society, Boston, MA, August 16-17, 2002; New York, NY, September 7-11, 2003**.**

Involvement in Professional Organizations (2003-2005)

Leadership

Chair and Program Chair for the Division of Agricultural and Food Chemistry (AGFD) of the American Chemical Society, 2003-2005. Responsible for organizing AGFD program for two ACS National Meetings (fall 2004 and spring 2005 meetings).

Symposia organized

Ho, C.-T., Weerasinghe, D.K. and Cadwallader, K.R. 2005. ACS Symposium: *Aroma-active compounds in foods and reaction flavors: formation, measurement and stability.* 330th ACS National Meeting, Washington, DC, August 28 – September 1.

Cadwallader, K.R., P. Schieberle and M.J. Morello. 2005. ACS Symposium: *Grain-based Products: Health and Flavor, and Safety Aspects.* 330th ACS National Meeting, Washington, DC, August 28 – September 1.

Cadwallader, K.R., Drake, M.A. and McGorrin, R.J. 2004. ACS Symposium: *Chemistry and Flavor of Dairy Products.* 228th ACS National Meeting, Philadelphia, PA, August 22-26.

Drake, M.A. and Cadwallader, K.R. 2003. IFT Symposium: *Flavor Chemistry of Dairy Products.* Annual Meeting of the Institute of Food Technologists, Chicago, IL, July 12-16, #52-5.

Funded Contracts/Projects (UIUC, 2000-present)

Cadwallader, K.R. Inverse Gas Chromatographic Measurement of Flavor Interactions with Solid Food Matrices under Controlled Relative Humidity. National Research Initiative Competitive Grants Program 71.1B, USDA, 2005-2008. $287,000.

Cadwallader, K.R. Soy Foods Managed Research Area. Illinois Soybean Program Operating Board. 2004-2005. $75,000

Cadwallader, K.R. (Klein, B.P, Khanna, P. collaborators) *Illinois Soy Foods Center for Research and Education.* Illinois Soybean Program Operating Board. 2004-2005. $100,000

Lee, S.-Y. and Cadwallader, K.R. Factors affecting astringency/bitterness in soy flakes and soy protein isolates (SPIs)[renewal]. Co-sponsored by Cargill Food Systems Design and Midwest Advanced Food Manufacturing Alliance – USDA (MAFMA). 2004-2005. $44,500

Klein, B.P., Khanna, P., Cadwallader, K.R. Introducing Soy Products in Illinois School Lunch Programs. Illinois Soybean Program Operating Board (ISPOB) and Archer Daniels Midland, $119,364.

Masel, R., Shannon, M., Strano, M. and Cadwallader, K.R. MEMS Gas Chromatograph with

Nanotube, Nanogate and microM8 detectors. The Defense Advanced Research Project Agency (DARPA). 2003-2007. approx. $4.5M.

Cadwallader, K.R. Soy Foods Managed Research Area. Illinois Soybean Program Operating Board. 2003-2004.. $25,000

Brewer, M.S., McKeith, F., and Cadwallader, K.R. Flavor profile and volatiles, color and Warner-Bratzler shear changes of five beef muscles enchanced prior to aging – long/short term. National Cattlemen's Beef Association. 2003-2004. $196,000.

Lee, S.-Y. and Cadwallader, K.R. Factors affecting astringency/bitterness in soy flakes and soy protein isolates (SPIs). Co-sponsored by Cargill Food Systems Design and Midwest Advanced Food Manufacturing Alliance – USDA (MAFMA). 2003-2004 $115,114 (Cargill), $46,677 (MAFMA).

Cadwallader, K.R. and Klein, B.P. Development of High-Energy, Nutrient-Dense Emergency Relief Food Product. Illinois Soybean Program Operating Board (ISPOB). 2002-2003. $15,000.

Cadwallader, K.R., Schmidt, S.J. and Feng, H. Comparison of Chemical and Physical Properties of Dried Strawberries Produced by Freeze Drying and Novel Film Drying Method. Midwest Advanced Food Manufacturing Alliance – USDA (MAFMA). 2002-2003. $35,455

Cadwallader, K.R. *Fruit Flavored RTEC Package Testing.* Kellogg Co. 2000-2002. $30,328.

Cadwallader, K.R. 2001-2003. *Testing of Food Materials, Food Ingredients, Food Films, and Food Packaging Materials using Dynamic Vapor Sorption (DVS) and DVS-Purge-and-Trap Fast-Gas Chromatography*. Kellogg Co. $59,936.

Cadwallader, K.R. 2000-2003. Instrumental Measurement of Swine Odor Compounds. Council on Food and Agricultural Research (CFAR-SRI). $180,000.

Cadwallader, K.R. and Klein, B.P. 2000-2003. *Flavor Properties of Soy Protein Isolates: Characterization of Bitter and Astringent Compounds and Their Relationship to Overall Flavor*. Kraft Foods, Inc. $153,000.

Klein, B.P. and Cadwallader, K.R. 2000-2004. *Establishing an Illinois Soy Foods Center for Research and Education.* Council on Food and Agricultural Research (C-FAR) Sentinal Grant Program. $1,041,600.

Drake, M.A. and Cadwallader, K.R. 2000-2004. *Development of Chemical Anchors to Cheddar cheese flavor lexicon terms. Dairy Management Inc*. $152,020.

Drake, M.A., Tong, P.S. and Cadwallader, K.R. 2000-2002. Development and Use of a Quantifiable Descriptive Language for Characterization of Milk Powders and Concentrates. California Dairy Research Foundation. $44,700.

DEHYDRATION OF FOODS

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CHAPTER 1

INTRODUCTION TO DEHYDRATION OF FOOD

1.0 INTRODUCTION

It is not known when the preservation of foods by dehydration began, but history does show that our ancestors learned how to dry foods by trial and error. Food dehydration eventually evolved within a scientific based environment and made possible the establishment of a worldwide industry, capable of providing a convenient and nutritious food supply.

The first record of drying is for vegetables, and appeared in the 18th century (Van Arsdel and Copley, 1963). Thereafter, the development of the drying industry was closely related to war scenarios around the world. British troops in the Crimea War (1854–1856) received dried vegetables from their homeland, Canadian dried vegetables were shipped to South Africa during the Boer War (1899–1902), and around 4500 tons of dehydrated vegetables were shipped from the United States during World War I. By 1919, among the products processed in the United States were green beans, cabbage, carrots,

celery, potatoes, spinach, sweet corn, turnips, and soup mixtures.

Fruit dehydration in the United States made a significant turn at the end of the 1800s and the beginning of the 1900s with the development of artificial dryers to replace sun drying. Drum drying and spray drying were investigated and developed before the Second World War, and used extensively for milk products and eggs.

Dehydration is especially suitable for military purposes because of the space and weight saving capabilities it affords. In the United States the production of dehydrated food evolved from processes developed for wartime uses to a vigorously growing branch of the entire food processing industry. Table 1.1 summarizes dried food production in the United States during 1992 and 1993.

Drying is a process in which water is removed to halt or slow down the growth of spoilage microorganisms as well as the occurrence of chemical reactions. The terms dried and dehydrated are not synonymous. The US Department of Agriculture lists dehydrated food as those with no more than 2.5% water (dry basis) while dried food apply to any food product that has been exposed to

Table 1.1 Summary of dried food production for 1992 and 1993.

Product	1992	1993	units
Nonfat dry milk	872	948	million pounds
Dry whole milk	168	153	million pounds
Dry whey	1237	1196	million pounds
Dry edible beans	22	22	million cwt
Fruits	619	557	million pounds

From USDA (1994).

a water removal process which has more than 2.5% water (dry basis).

In addition to preservation, drying is used to reduce the cost or difficulty of packaging, handling, storing, and transporting by converting the raw food to a dry solid. This reduces the weight and sometimes the volume.

1.1 THEORETICAL ASPECTS

Theoretical concepts such as moisture content, dry and wet bulb temperature, relative humidity, humid heat, dew point, saturation condition, adiabatic saturation, water and enzymatic activity, microbial spoilage, crispness, viscosity, hardness, aroma, flavor, palatability, drying periods, and theories on mass transfer phenomena are discussed from the dehydration perspective in Chapters 2, 3, and 4.

The removal of water from a food is achieved mainly by use of dry air (except for some unit operations such as freeze drying and osmotic dehydration) which picks up the water from the surface of the product and carries it away. The engineering concepts used to explain the water–air relationship are presented in Chapter 2. Also included is an introduction to the design of an ideal dryer and mass and heat balances.

The process of drying foods not only affects the water content of the product, but other physical and chemical characteristics as well. Among the characteristics used to describe dried foods are water activity; sorption isotherms; microbial spoilage; enzymatic and nonenzymatic reactions; physical and structural phenomena; and destruction of nutrients, aroma, and flavors. Chapter 3 presents a comprehensive discussion of these characteristics and their implications in food dehydration.

What mechanisms are involved in the movement of water during the dehydration process? They can be sum-